Feasibility study into - Bio-reactor systems

In principle bio-reactors use naturally endowed ‘living creatures’ to convert or produce materials. More specifically reactors use immobilised enzymes, microorganisms (bacteria), and animal or plant cells to convert waste material. In recent years there has been work on genetically engineering bacteria to specifically target certain waste and convert it into useful products.

The main difference between conventional reactors is both the use of microorganisms and the reactors lower operating temperatures and pressures to avoid denaturation. The most effective bio-reactor model is its combination with membranes which is an emerging technology within water waste treatment.

# Extractive membrane bioreactors

This technology exploits the membranes ability to achieve a high degree of separation while allowing transport of material from one phase to another. The membrane is immersed into a ‘bio-medium’ tank where toxic materials are transferred into it from the membrane by mass transfer. The specialised microbial cultures could be cultivated in the reactor and can be optimised for the degradation of the waste water constituents. Within the bio-reactor there would be active temperature, PH, dissolved oxygen and nutrient monitors.

**Waste water**

**Treated wastewater**

Effluent

Hollow fibre membrane

The extractive membrane bioreactors have the advantage of being modular, which would be beneficial in a mars space station. Therefore increasing capacity is relatively simple. The level of effluent is likely to be lower than conventional bio-reactor technologies; however it is relatively unproven at full scale.

# Recycle membrane reactors

This bioreactor is made up of a reaction vessel operated as a stirred tank reactor with an externally attached membrane module. Like a batch reactor, the waste water and the microorganisms are added at the beginning with their composition pre-determined. The mixture is continuously pumped through the external membrane circuit. One of the issues associated with biological batch processes is fouling of the microorganisms on the membrane surface. Regular maintenance is needed which would be challenging on an 18 month stay on Mars especially if parts need to be replaced. Once the process is complete the microbial population is separated from the end product. The constant removal of product means there is a lower chance of it inhibiting future degradation and even poisoning the biocatalyst.

# Composition of waste water

# It is necessary to understand the composition of the wastewater on Mars. It is like to be composed of Urea (2000 mg/L) , NaCl (1000 mg/L), body soap (2000 mg/L) and creatine (200 mg/L) (Choi, et.al, 2006). Moreover nutrients necessary for the growth of microorganisms need to be added to waste water mixture. For the nitrification most of the microorganisms that need to be used are ammonium oxidising bacteria (Smith and Oerther, 2005). As a result PH needs to be closely monitored and controlled by using 10% (wt/vol) sodium carbonate buffer solution to ensure the PH is between 7.0 and 7.5.

# Overall membrane bio-reactors are an effective technology to reduce the need to deal with multiple phases in a variety of life support subsystems. They offer significant advantages over conventional activated sludge processes, including higher biomass concentration and enhanced nitrification. However microorganisms combined with a physical membrane will often result in irreversible membrane bio-fouling which requires constant cleaning or even replacement of the membrane. If membranes are to be used in space a comprehensive solution is needed as this is one of the technologies limiting factors. On earth chemical cleaning or replacement is easy but expensive, and that capacity will not always be available on Mars.

# Challenges

Typically the microorganisms would degrade the pollutants within the waste water aerobically i.e. requiring a supply of oxygen. This would increase the supply of air needed which is one of its disadvantages as breathing air in itself is a significant challenge. However each bio-reactor is different and requires slightly different levels of air. Conventional activated sludge processes air supply is very inefficient with 80-90% of the oxygen diffused as air is vented to atmosphere. Therefore oxygenation with pure oxygen rather than air would lead to an increase in the overall mass transfer and biodegradation rate. It would be difficult to imagine that the amount of oxygen needed for approximately 137271 kg of water can be resupplied every 18 months. Moreover increasing the output of ‘air recycling’ isn’t impossible but it would pose a significant challenge.

Another cause of concern is the reliance on microorganisms for life support. By nature they are very sensitive especially to denaturation from either an increase in temperature or drop in PH. Therefore it would be a challenge to ensure the microorganisms not only survive the lengthy trip to mars but that they are able to grow throughout the 18 month duration. But if microorganisms can be sustained throughout the 18 month period bio-reactors using membrane would be an appropriate technology. It can remove both soluble ions and particulates as well using either microfiltration of ultrafiltration in a single phase reactor. Moreover treating water biologically is advantageous as it closely mimics the natural process for various nutrient cycles (including carbon and nitrogen), and can be integrated into a comprehensive water reuse system more easily (Choi, et.al, 2006).

Further challenges include the surfactant in the soap used by the crew members and nitrogen in the urine. Surfactants could cause significant foaming in the treatment process which could pose fouling problems (Choi, et.al, 2006). The oxidation of the nitrogen in the urine requires ammonification by the urease enzymes that convert organic nitrogen to ammonium (Choi, et.al, 2006). The microorganism therefore needs to be adapted to cope with large levels of surfactant and ammonium for an 18th month period.